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Carlson et al.

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(54) **MULTIPLE DISC ARRAY CARRIER**

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H05K 7/16 (2006.01)

(52) **U.S. Cl.** **361/724**; 361/685; 312/223.2

(58) **Field of Classification Search** 361/684, 361/685, 724–727; 312/223.1, 223.2
See application file for complete search history.

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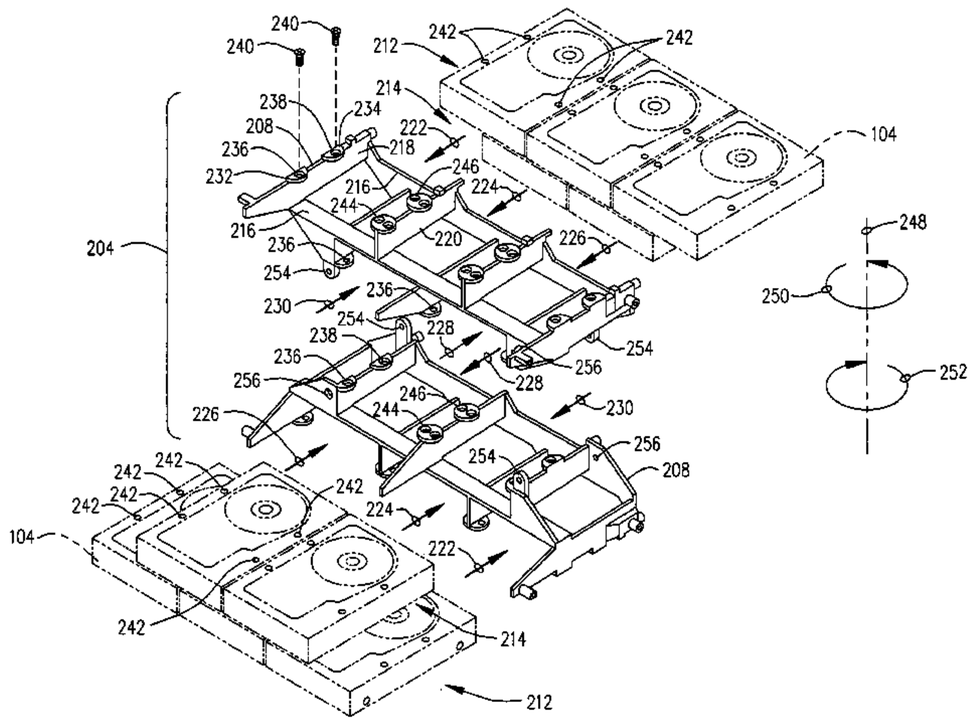
(57) **ABSTRACT**

A multiple disc array apparatus and associated method are provided having substantially identical first and second partitions that are removably connectable together. Each partition supports a plurality of data storage devices arranged in noncoplanar first and second arrays. Each partition further defines clearance apertures for passing fasteners therethrough for fixing each data storage device to the respective partition.

19 Claims, 7 Drawing Sheets



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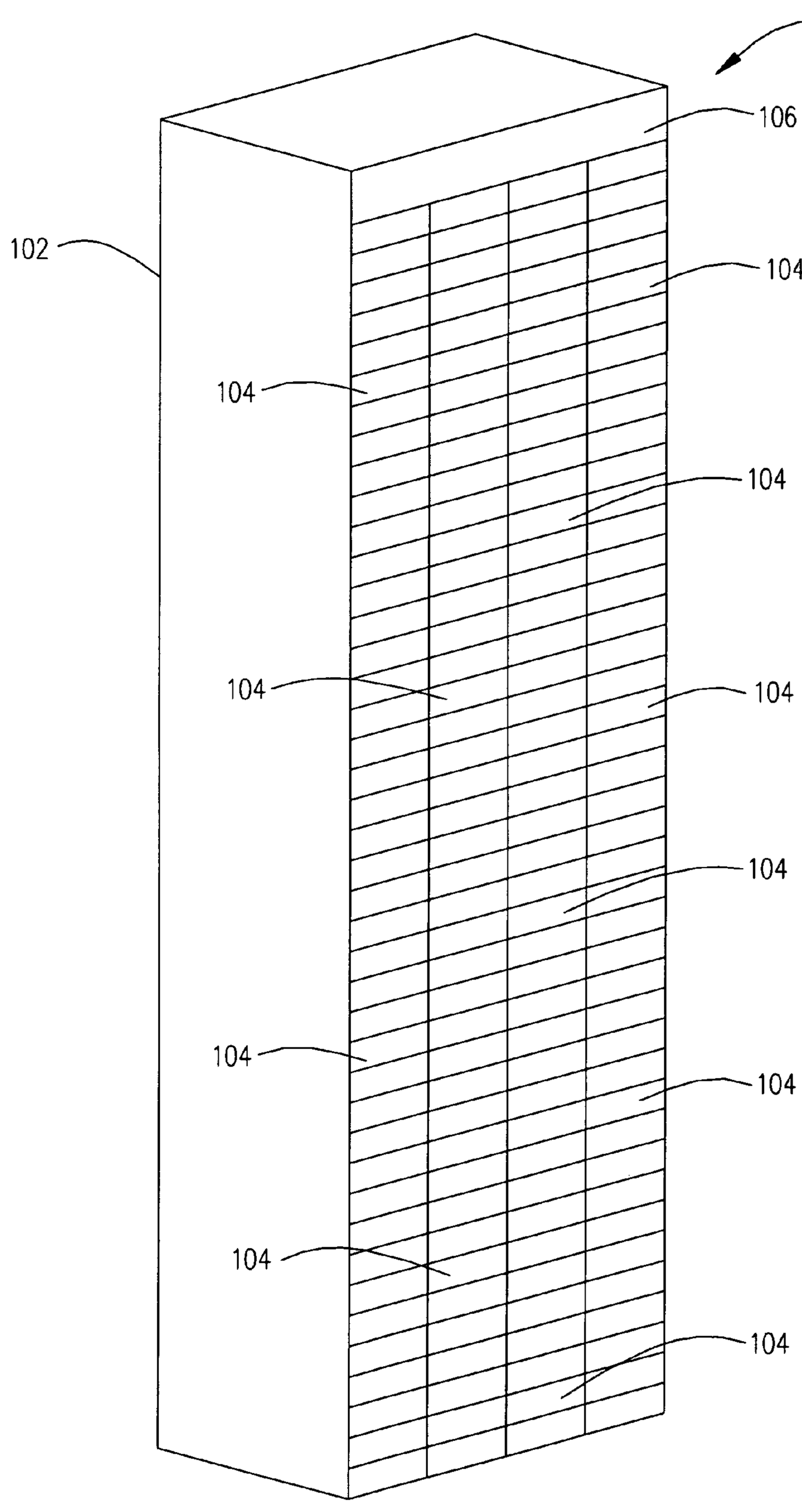

FIG. 1
RELATED ART

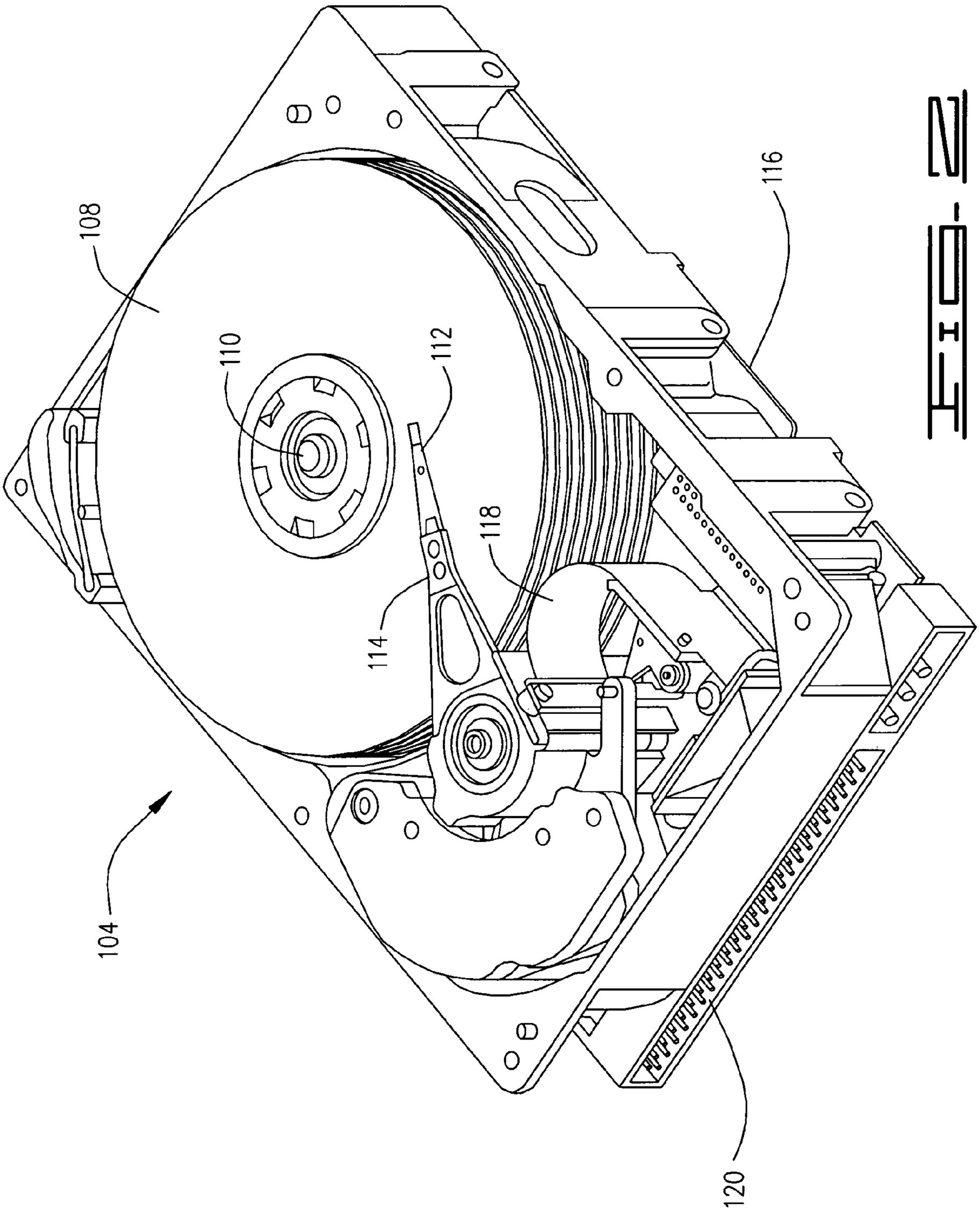

FIG. 2

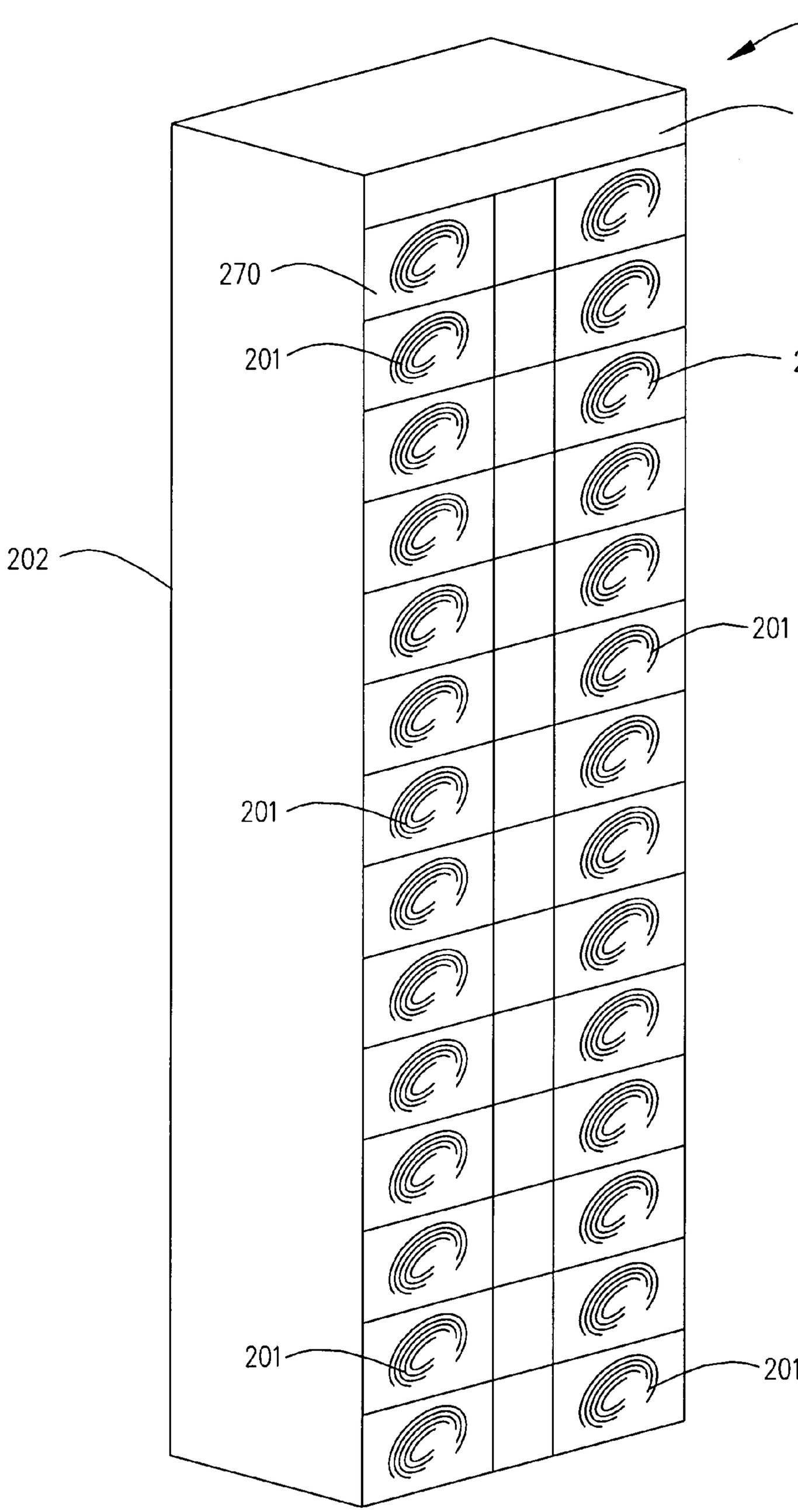

FIG. 3

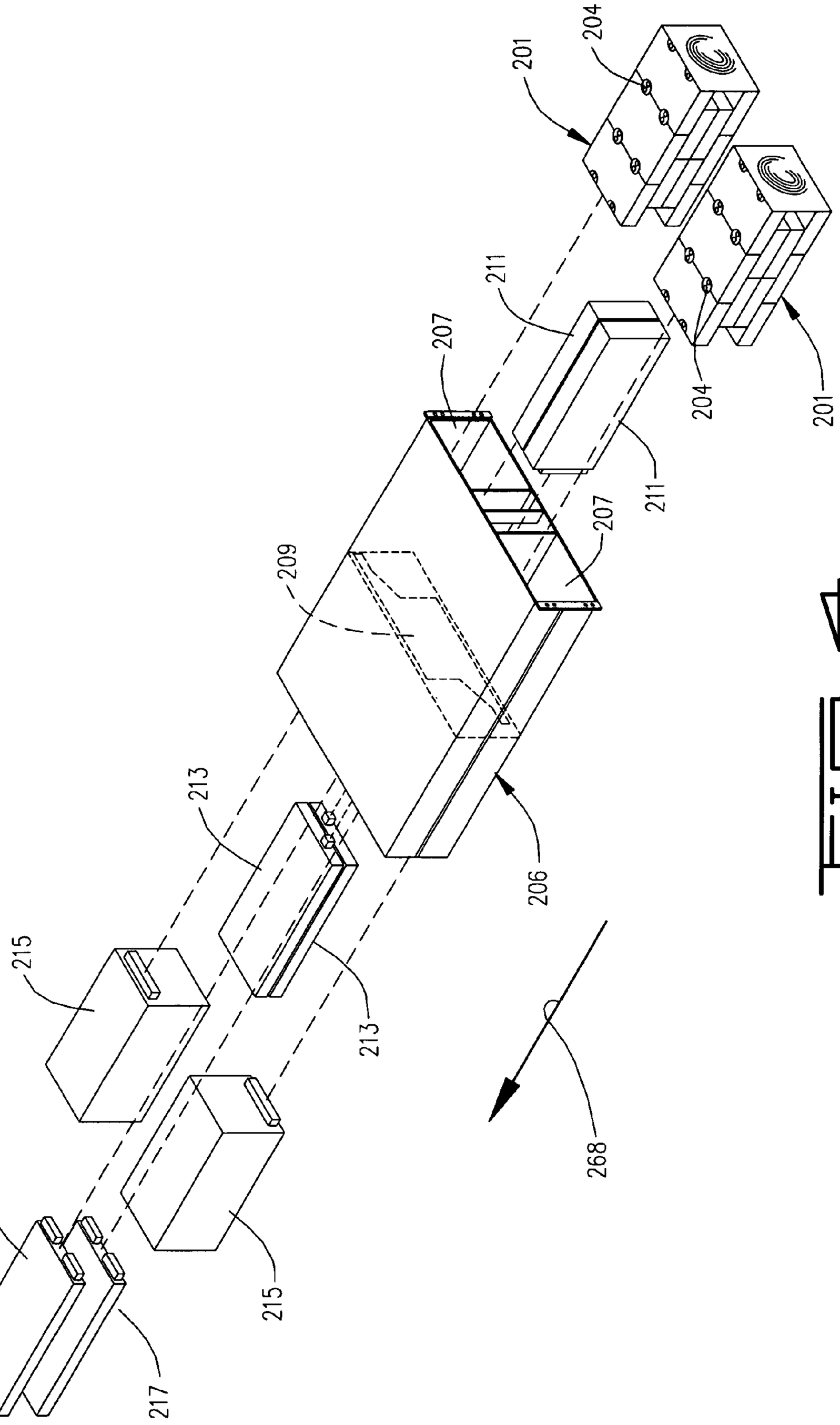

FIG. 4

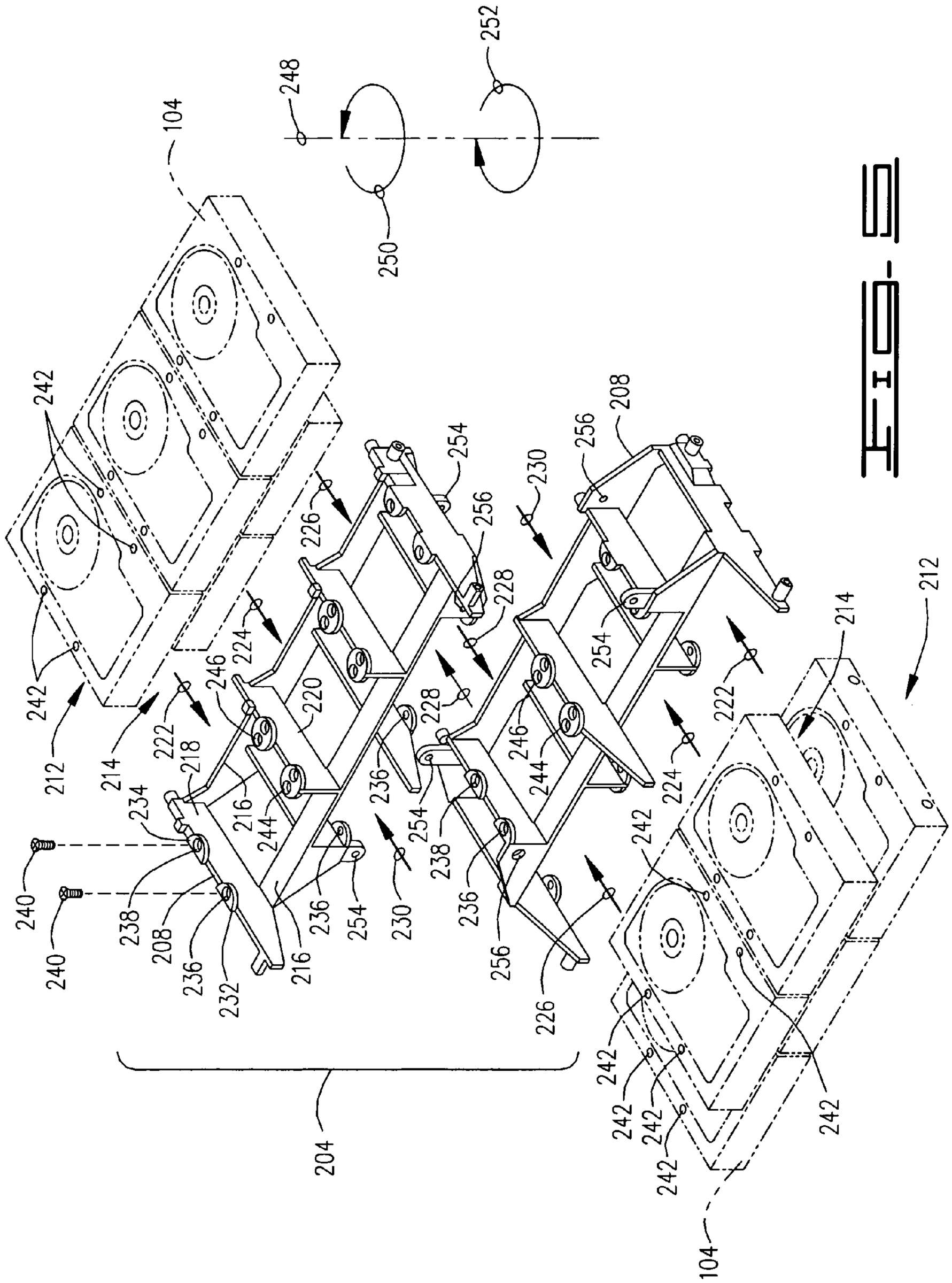
104
248
252
250
242
212
214
222
218
234
240
238
208
236
232
216
244
246
220
224
226
254
256
228
230
204

Fig-5

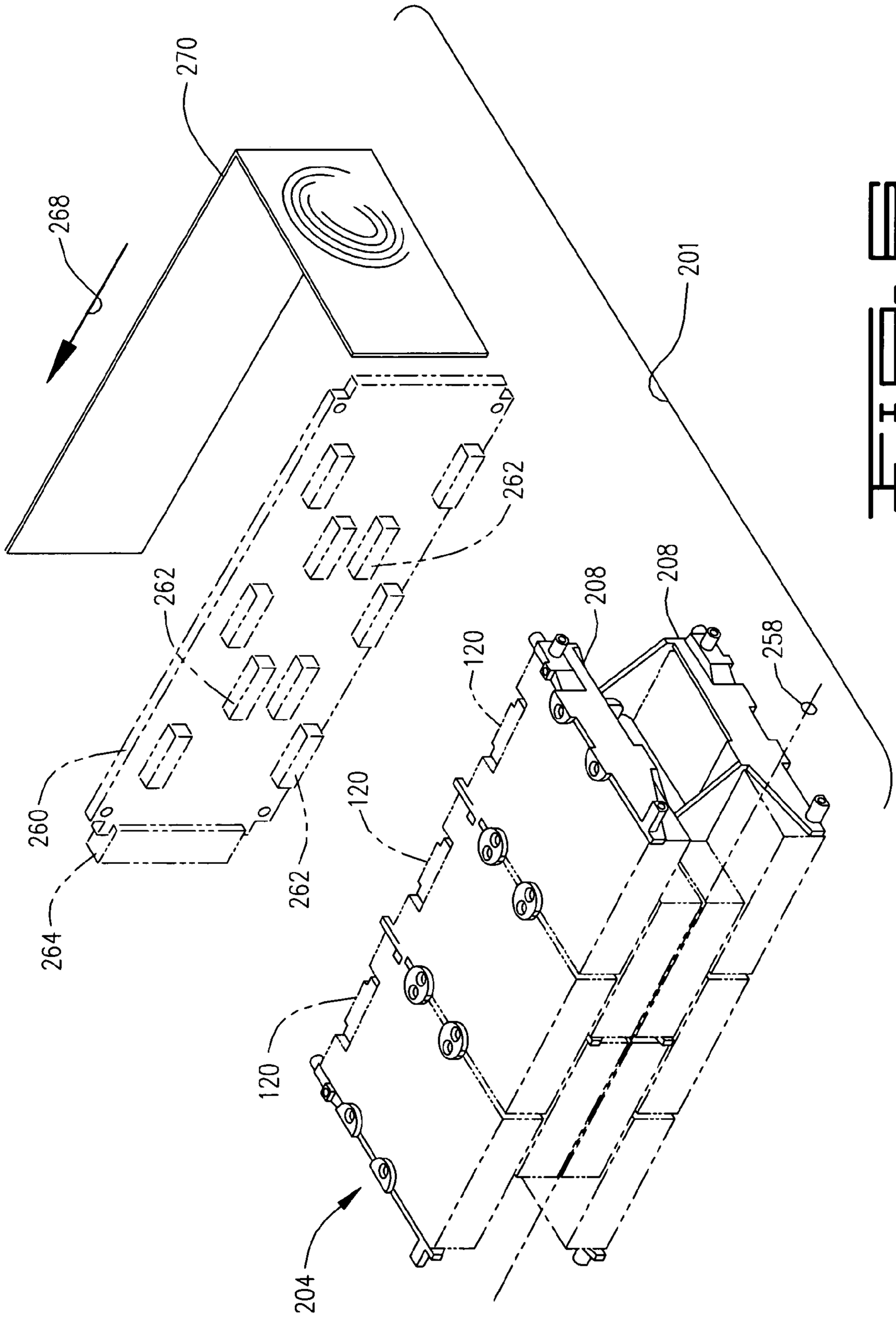

FIG-11

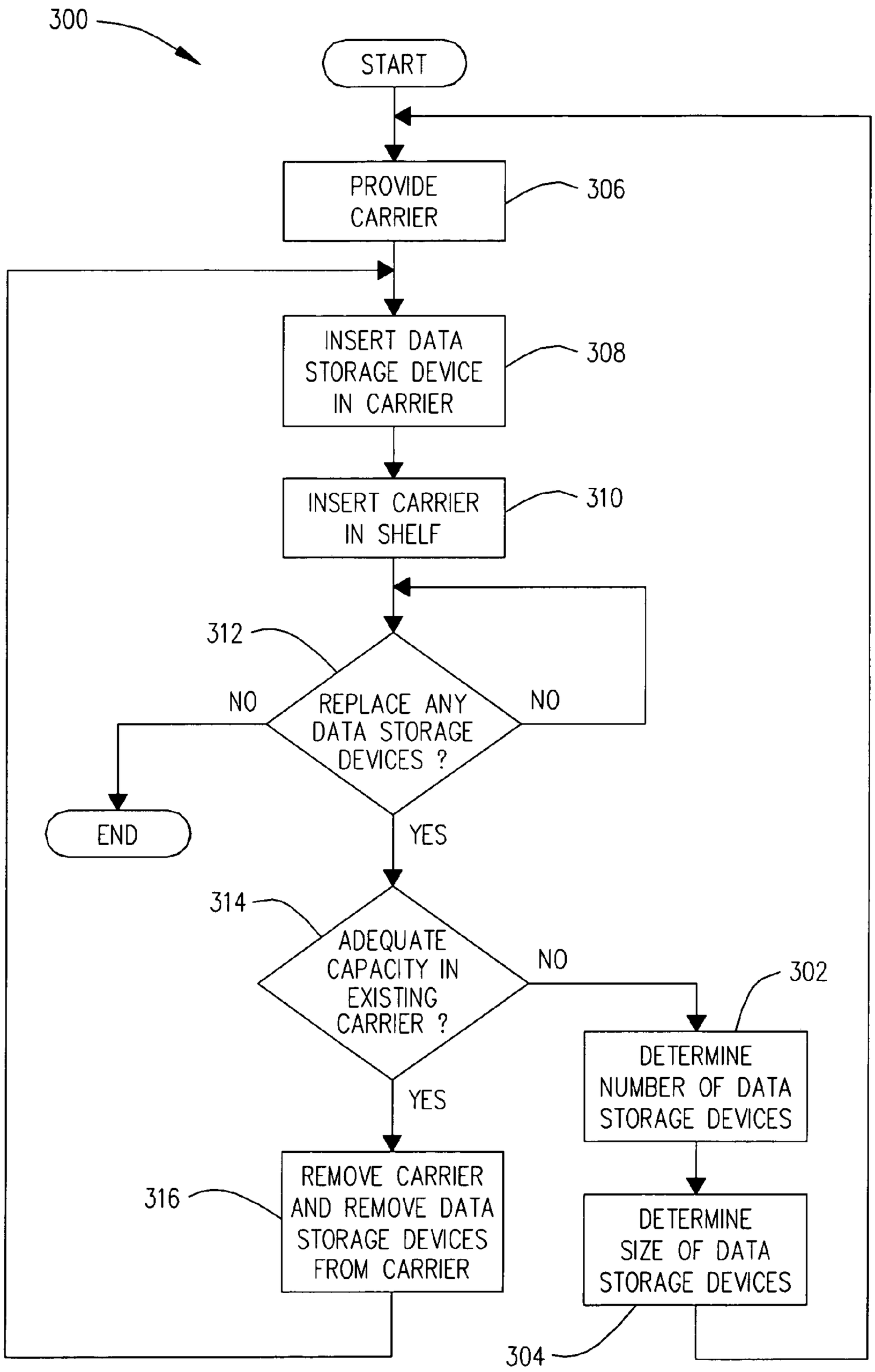
300
START
PROVIDE CARRIER
306
INSERT DATA STORAGE DEVICE IN CARRIER
308
INSERT CARRIER IN SHELF
310
312
REPLACE ANY DATA STORAGE DEVICES ?
NO
NO
YES
END
314
ADEQUATE CAPACITY IN EXISTING CARRIER ?
NO
302
DETERMINE NUMBER OF DATA STORAGE DEVICES
YES
316
REMOVE CARRIER AND REMOVE DATA STORAGE DEVICES FROM CARRIER
DETERMINE SIZE OF DATA STORAGE DEVICES
304

FIG. 7

MULTIPLE DISC ARRAY CARRIER

RELATED APPLICATIONS

This is a continuation of co-pending U.S. patent application Ser. No. 10/884,605 filed Jul. 2, 2004.

FIELD OF THE INVENTION

The embodiments of the present invention relate generally to the field of array storage systems and more particularly but without limitation to a carrier for convertibly componentizing various numbers and sizes of data storage devices to define a multiple disc array.

BACKGROUND

Ever-increasing demand for data storage capacity has fostered the development of improved data array storage systems wherein a plurality of data storage devices is electronically linked to function synergistically. Data integrity schemes are also enhanced in such arrays permitting fail-safe redundant storage of data, such as in redundant arrays of independent device ("RAID") systems.

There are a number of challenges facing the array designer. For example, the many and complex mechanical and electrical connections required for each data storage device are multiplied by the number in an array. That is, each and every data storage device requires sufficient mechanical support to isolate the delicate head and disc components from vibration levels that create data transfer errors. Not only must attention be paid to self-excitation, that is, vibration caused by the rotating disc of a data storage device itself, but like attention is required to external excitation sources in such an environment. External excitation can come from other data storage devices in the array, electrical components in the array such as power supplies and fans, and from the installation and/or removal of data storage devices while the array is operational.

As the number of data storage devices in arrays increases, the problems associated with electromagnetic interference containment are exacerbated as well. Properly shielding the data storage devices requires attention paid not only to leak paths between drives in adjacent shelves, but also to the leak paths potentially created by the multiple openings into which each of the plurality of data storage devices is inserted. Adequate shielding of these openings must be provided while still permitting the ability to insert and/or remove a data storage device without disrupting the shielding in place for adjacent data storage devices in the array.

Flexibility can be a problem as well. For instance, traditionally the electrical systems, such as the connector boards, controllers, and connecting buses, are hard-wired for a predetermined number and size of data storage devices in the array. This is required to maintain the electrical integrity of the array while permitting swapping of individual data storage devices. For this reason, the storage shelves and the associated electrical systems are dedicated for the predetermined number and size of data storage devices. Accordingly, because of both mechanical and electrical constraints, an array designed for a particular form factor configuration cannot readily be adapted for use with a different form factor. Also, if a grouping of data storage devices is needed for a particular function, such as mirroring the storage of data, such functionality must conventionally be achieved at the top level host programming level. This requires complex and coordinated programming of many data storage devices.

While various approaches have been proposed in the art to address maximizing the data storage capacity while also providing operable flexibility in the utilization of data storage devices in array storage systems, there nevertheless remains a continued need for improvements in the art. It is to such improvements that the claimed invention is directed.

SUMMARY OF THE INVENTION

In accordance with preferred embodiments of the present invention, an apparatus and method are contemplated for convertibly componentizing data storage devices in a multiple disc array.

In some embodiments a multiple disc array is provided having substantially identical first and second partitions that are removably connectable together. Each partition supports a plurality of data storage devices arranged in noncoplanar first and second arrays. Each partition further defines clearance apertures for passing fasteners therethrough for fixing each data storage device to the respective partition.

In some embodiments a method is provided for fixing a first plurality of data storage devices to a first partition arranged in noncoplanar first and second arrays; fixing a second plurality of data storage devices to a second partition arranged in noncoplanar third and fourth arrays; and joining the first and second partitions together forming a multiple disc array.

In some embodiments a multiple disc array is provided having a plurality of data storage devices, with each having a transducer in a data transfer relationship with a storage medium, and means for supporting the plurality of data storage devices to maximize packing density while minimizing the number of unique supporting members.

These and various other features and advantages which characterize the claimed invention will become apparent upon reading the following detailed description and upon reviewing the associated drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an isometric view of an array storage system constructed in accordance with related art solutions.

FIG. **2** is an isometric view of a data storage device.

FIG. **3** is an isometric view of an array storage system constructed in accordance with embodiments of the present invention.

FIG. **4** is an exploded isometric view of portions of the array storage system of FIG. **3**.

FIG. **5** is an exploded isometric view of the carrier portion of FIG. **4**.

FIG. **6** is an exploded isometric view of the multiple disc array of FIG. **3**.

FIG. **7** is a flow diagram of a method for componentizing a selected number and size of data storage devices as a multiple disc array in accordance with embodiments of the present invention.

DETAILED DESCRIPTION

FIG. **1** is an isometric view of a related art array storage system **100** wherein a cabinet **102** supports a plurality of data storage devices **104**. A host **106** is electrically connected to each of the data storage devices **104** so as to provide a bulk data storage arrangement, such as for providing a network interface and/or for employing data integrity schemes such as in a RAID system.

FIG. **2** is an isometric view of a data storage device **104** suited for use with the present invention and in the form of a

rotating magnetic media disc drive. A data storage disc **108** is rotated by a motor **110** to present data storage locations of the disc **108** to a read/write head ("head") **112**. The head **112** is supported at the distal end of a rotary actuator **114** that is capable of moving the head **112** radially between inner and outer tracks of the disc **108**. The head **112** is electrically connected to a circuit board **116** by way of a flex circuit **118**. The circuit board **116** is adapted to receive and send control signals controlling the functions of the data storage device **104**. A connector **120** is electrically connected to the circuit board **116**, and is adapted for connecting the data storage device **104** with control electronics of the array **100**.

The array storage system **100** offers one way of combining the storage capability of a number of data storage devices **104**. Disadvantageously, however, the individual openings in the cabinet **102** are sized and wired to receivingly engage either individual data storage devices **104**, or a fixed number and size of data storage devices **104**.

FIGS. **3** and **4** illustrate an array storage system **200** constructed in accordance with novel embodiments of the present invention, wherein a plurality of multiple disc arrays ("MDA") **201** are utilized. An MDA **201** generally comprises a convertible plurality of componentized data storage devices **104**. By "convertible" it is meant that one or more data storage devices **104** can be readily replaced, added, or removed in an existing MDA **201**, or that a different MDA can be utilized that is capable of supporting a different number, size or arrangement of data storage devices. By "componentized" it is meant that the data storage devices **104** and associated control electronics in the MDA **201** are integrated so as to be functionally presented to the array **200** as a single component.

A cabinet **202** defines a plurality of cavities into each of which a shelf **206** is receivingly engaged. Each shelf **206** defines one or more cavities **207** into each of which an MDA **201** is receivingly engaged for engagement with a backplane **209**. Similarly, the shelf **206** defines cavities for receivingly engaging other electrical modules with the backplane **209**, such as, but not limited to, controllers **211**, batteries **213**, power supplies **215**, and interfaces **217**.

In the illustrative embodiment of FIG. **4**, the shelf **206** defines two cavities **207** for receiving two MDAs **201**. Equivalent alternative embodiments contemplate a different number of MDAs **201** per shelf **206**. The array storage system **200** comprises a plurality of MDAs **201**, each sized in accordance with the respective cavity **207** for an operable mating relationship. Each MDA **201** is adapted to operably support a variable number, size, or arrangement of data storage devices **104**. More particularly, this solution provides an array storage system **200** comprising a shelf **206** for receivingly engaging an MDA **201** comprising a carrier **204** from a plurality of different carriers, each carrier of the plurality having common exterior dimensions defining an operable mating relationship with the cavity **207** of the shelf **206**, and each carrier of the plurality differentiated by interior supporting features for supporting a selected number, size, or arrangement of data storage devices **104**.

FIG. **5** is an exploded isometric view illustrating embodiments wherein the carrier **204** comprises a pair of identical partitions **208** that are joined together. In this arrangement the joined partitions **208**, each supporting a plurality of data storage devices **104**, are receivingly engageable within one cavity **207** of the shelf **206** (FIG. **4**) which is, in turn, receivingly engageable within the cavity of the cabinet **202** (FIG. **4**). In some embodiments of the present invention, the shelf **206** is fixed within the cabinet **202** and the carrier **204** is insertable and removable from the shelf **206** so that individual data storage devices **104** can be readily added, removed or replaced. In other embodiments of the present invention, a carrier **204** can be replaced with another carrier having different data storage device supporting features for electrically connecting a different selected number, size, or arrangement of data storage devices **104** in the shelf **206**.

In the illustrative embodiments of FIG. **5** the partition **208** supports a first linear array **212** of three data storage devices **104** and a second linear array **214** of two data storage devices **104**. The partition **208** defines a planar support surface **216** and opposing transverse side members **218**, **220** defining a channel **222** for receivingly engaging one of the data storage devices **104** therein. Similarly, channels **224**, **226** are defined for receivingly engaging the other two data storage devices **104** in the first array **212**, and channels **228**, **230** are defined for receivingly engaging the data storage devices **104** in the second array **214**.

Tab members **232**, **234** extend transversely from the distal end of the side member **218** and define attachment points **236**, **238**, respectively, for fixing the data storage device **104** to the partition **208**. In some embodiments the attachment points **236**, **238** can comprise a clearance aperture for passing a fastener **240** therethrough for engaging an attachment feature **242** of the data storage device **104**. For example, the fasteners **240** can comprise threaded fasteners that threadingly engage threaded openings **242** provided in the data storage device **104**. In the illustrative embodiments of FIG. **5** there are four attachment points **236**, **238**, **244**, **246** for fixing each data storage device **104**. Positively fixing each of the data storage devices **104** to the partition **208** in this manner advantageously damps vibration created by the rotating discs **108**.

It will be noted that the data storage devices **104** in the second array **214** must be flipped, with respect to those in the first array **212**, in order for the attachment features **242** to align with the attachment points **236**, **238**, **244**, **246** associated with the channels **228**, **230**. This causes the data storage devices **104** in the first array **212** to spin oppositely with respect to data storage devices **104** in the second array **214**. That is, with respect to a reference axis of rotation **248** that is parallel with the axis of rotation of all data storage devices **104**, if the data storage devices **104** in the first array **212** operably rotate in direction **250**, then by the flipped relational orientation the data storage devices **104** in the second array **214** will rotate oppositely in direction **252**.

This opposite rotation of data storage devices **104** in different arrays **212**, **214** reduces vibration in comparison to arrangements where all the data storage devices **104** spin in the same direction. For example, differential rotational vibration is effectively canceled between adjacent, oppositely rotating data storage devices **104** rather than being accumulated by rotating in the same direction.

For illustrative embodiments of FIG. **5**, first attachment features **254** are alignable with second attachment features **256** for joining the two partitions **208** together. For example, the first attachment feature **254** can define a clearance aperture for passing a fastener (not shown) therethrough and fixingly engaging the second attachment feature **256**.

FIG. **6** illustrates embodiments wherein the two partitions **208** are joined together along a demarcation axis **258** to form the carrier **204**. In alternative equivalent embodiments the carrier **204** could comprise only one partition **208**. It will be noted that by first fixing all the data storage devices **104** to the respective partitions **208** and then connecting the partitions **208** together that the attachment features **236**, **238**, **244**, **246** are readily accessible for all data storage devices. To maximize the vibration-reducing benefits of the oppositely-spin-

ning data storage devices **104**, the arrays **212**, **214** are disposed substantially parallel to and mirrored around the demarcation axis **258**.

Within the carrier **204**, each of the data storage devices **104** has the electrical connector **120** disposed within a coplanar arrangement of all connectors **120** of all the data storage devices **104**. The carrier **204** supports a circuit board **260** having a number of connectors **262** arranged to align with the connectors **120** of the respective data storage devices **104**. The circuit board **260** preferably further has a connector **264** that is adapted to connect to the electronics of the array storage system **200** via the backplane **209** (FIG. **4**). It will be noted that in the illustrative embodiments of FIG. **6**, the connector **264** is aligned for an operable insertion connection with the backplane **209** by moving the circuit board **260** in a direction **268** along the longitudinal depth of the shelf **206** (FIG. **4**). In this manner, the electrical connection between the circuit board **260** and the array storage system **200** is readily made as a result of inserting the MDA **201** into the shelf **206** (FIG. **4**). The circuit board **260** is selectively configured such that upon operative insertion of the carrier **204**, the host **106** can be placed in electrical communication with each and every data storage device **104** in the MDA **201**, and the data storage devices **104** can be in electrical communication with other data storage devices **104** both inside and outside a particular MDA **201**.

The carrier **204** can support a wrapper **270** for enclosing the data storage devices **104** and/or the circuit board **260** for electrical shielding. In the illustrative embodiments of FIG. **6** the wrapper **270** covers just the front and circuit board portions of the MDA **201**. The carrier **204** also preferably comprises one or more guide members that are adapted for aligning with mating features in the backplane **209** (FIG. **4**) to positively align the MDA **201** during insertion.

FIG. **7** is a flow chart of illustrative steps for a method **300** for supporting a plurality of data storage devices **104** in an MDA **201** in accordance with embodiments of the present invention. The method **300** initially determines the number of data storage devices **104** desired in step **302** and the size of the data storage devices **104** desired in step **304**. From these determinations, an appropriately configured carrier **204** can be selected in step **306**. It will be noted that the number and size of the supporting channels **222** do not have to exactly match the number of data storage devices **104** desired; rather, a carrier **204** with currently unused channels **222** can be used in future expansion of capacity by adding more data storage devices **104** in the same carrier **204**.

The data storage devices **104** are inserted into the carrier **204** in step **308**. The insertion step comprises fixing a first data storage device **104** to the partition **208**, and fixing a second data storage device **104** to the partition **208** in an orientation establishing an opposite direction of disc **108** rotation with respect to the first data storage device **104**. In some embodiments the insertion step further comprises fixing a third data storage device **104** to another identical partition **208** and connecting the partitions **208** together. The carrier **204** is then inserted into the shelf **206**.

Decision step **312** determines whether any presently employed data storage devices **104** need to be changed, such as for maintenance, repair, archiving or the like. If yes, then decision block **314** determines whether there is an adequate capacity of supporting channels in the presently used carrier **204**. If yes, such as when one data storage device **104** is being replaced with an identical one, then in step **316** the carrier **204** is removed from the shelf **206** and one or more data storage devices **104** are removed from the carrier **204**. The method then returns to step **308** where one or more data storage devices **104** are inserted into the carrier **204**.

If the determination of step **314** is no, then a differently configured carrier is needed. The method returns to step **302** and **304** which define the appropriate carrier, and the method returns to the providing the carrier step **306**.

Summarizing, a carrier (such as **204**) is used for componentizing a number of data storage devices (such as **104**) in an MDA (such as **201**). The carrier is unitarily removable and insertable in a shelf (such as **206**) of an array storage system (such as **200**). The carrier comprises a partition (such as **208**) defining an arrangement of channels (such as **222**) for receivingly engaging a data storage device. The number of channels is associated with the selected number of data storage devices, and the size of the channels is associated with the selected size of the data storage devices. The partition further defines attachment points (such as **232**) for fixing the data storage device to the partition.

The partition supports a first array (such as **212**) of data storage devices and a second array (such as **214**) of data storage devices, such that a data storage device in the first array operably spins oppositely with respect to a data storage device in the second array. The carrier can comprise two partitions, each supporting arrays of data storage devices, that are connected together along a demarcation axis (such as **258**). The data storage devices can be disposed substantially parallel to and in a mirrored arrangement around the demarcation axis. Preferably, an equivalent number of data storage devices are supported in the partitions.

The data storage devices are supported in the carrier such that an electrical connector (such as **120**) of each is disposed within a coplanar arrangement of all the connectors of the data storage devices in the MDA. The carrier supports a circuit board (such as **260**) for operatively connecting the selected number of data storage devices in the MDA. A wrapper (such as **270**) can enclose the carrier and/or circuit board for electrical shielding.

Embodiments of the present invention contemplate a method for supporting a data storage device in an array storage system. The method comprises providing a carrier (such as **306**) from a plurality of different carriers that is insertable in a shelf supported in the array storage system; the carrier defining an arrangement of channels that each supportingly engage a data storage device, wherein the number of channels is associated with a selected number of data storage devices, and wherein the size of each channel is associated with a selected size of the data storage device, and wherein the different carriers have common volumetric dimensions but varying number and/or size of channels. The method further comprises inserting one or more data storage devices in a respective number of channels in the carrier (such as **308**). The insertion step comprises fixing a first data storage device to the partition, and fixing a second data storage device to the partition in an orientation establishing an opposite direction of disc rotation with respect to the first data storage device. In some embodiments the insertion step further comprises fixing a third data storage device to another identical partition and connecting the partitions together. The carrier is then inserted into the shelf in step **310**.

The method further comprises the replacing of an existing data storage device in the array storage system, by removing the carrier from the shelf and removing a data storage device from the carrier (such as **316**), inserting another data storage device in the carrier (such as **308**), and inserting the carrier back in the shelf (such as **310**). The method of replacing an existing data storage device in the array storage system can furthermore comprise removing the carrier from the shelf,

and inserting a different carrier supporting one or more data storage devices in the shelf (such as **302**, **304**, **306**).

Present embodiments contemplate a multiple disc array having a plurality of data storage devices, each having a transducer in a data transfer relationship with a storage medium, and means for supporting the plurality of data storage devices to maximize packing density while minimizing the number of unique supporting members. For purposes of this description and meaning of the appended claims, the term "means for supporting" requires the structure disclosed herein and equivalents thereof that provides closely packed channels that receivingly engage and fixingly support each of the data storage devices for providing maximum packing density of the data storage devices. The term "means for supporting" also requires that the first and second partitions be substantially identical in order to minimize the number of unique parts involved in manufacturing the multiple disc array.

It is to be understood that even though numerous characteristics and advantages of various embodiments of the present invention have been set forth in the foregoing description, together with details of the structure and function of various embodiments of the invention, this detailed description is illustrative only, and changes may be made in detail, especially in matters of structure and arrangements of parts within the principles of the present invention to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed. For example, the particular elements may vary depending on the particular configuration of the channel surfaces defining the channels without departing from the spirit and scope of the present invention.

What is claimed is:

1. A multiple disc array comprising substantially identical first and second partitions that are removably connectable together, each partition supporting a plurality of data storage devices arranged in noncoplanar first and second arrays, and each partition further defining clearance apertures for passing fasteners therethrough for fixing each data storage device to the respective partition.

2. The multiple disc array of claim **1** wherein each partition defines a plurality of channels, wherein each channel receivingly engages a data storage device.

3. The multiple disc array of claim **2** wherein each channel is defined by a planar support surface and opposing side members extending from the planar support surface, and wherein tab members are disposed at distal ends of the side members opposing the planar support surface.

4. The multiple disc array of claim **3** wherein the tab members define the clearance apertures.

5. The multiple disc array of claim **1** wherein a data storage device in the first array operably spins oppositely with respect to a data storage device in the second array.

6. The multiple disc array of claim **1** wherein the fasteners comprise threaded engagement members.

7. The multiple disc array of claim **1** wherein the plurality of data storage devices in the first and second arrays has electrical connectors that are operably disposed in a coplanar relationship.

8. The multiple disc array of claim **7** comprising a planar printed circuit board with mating electrical connectors that operably connect to the data storage device connectors.

9. The multiple disc array of claim **8** wherein the printed circuit board comprises an external connector that is electrically connected to each of the mating connectors, for placing the plurality of data storage devices in communication with another device.

10. The multiple disc array of claim **9** wherein an insertion direction for connecting the data storage devices to the mating connectors is substantially orthogonal to an insertion direction for connecting the external connector to the other device.

11. A method comprising:

fixing a first plurality of data storage devices to a first partition arranged in noncoplanar first and second arrays;

fixing a second plurality of data storage devices to a second partition arranged in noncoplanar third and fourth arrays; and

joining the first and second partitions together forming a multiple disc array.

12. The method of claim **11** wherein the fixing steps are characterized by the first and second partitions being substantially identical.

13. The method of claim **11** wherein the fixing steps are characterized by each partition defining clearance apertures for passing fasteners therethrough.

14. The method of claim **11** wherein the fixing steps are characterized by slidingly engaging the data storage devices into channels defined by the first and second partitions.

15. The method of claim **11** wherein the fixing steps are characterized by flipping data storage devices in the second array with respect to the first array, and by flipping data storage devices in the fourth array with respect to the third array, so that the data storage devices in the first and second arrays operably spin oppositely and data storage devices in the third and fourth arrays operably spin oppositely.

16. The method of claim **13** wherein the fixing steps are characterized by using threaded fasteners.

17. The method of claim **15** further comprising electrically connecting each of the data storage devices to a common printed circuit board.

18. The method of claim **17** further comprising electrically connecting the common printed circuit board to an external circuit.

19. The method of claim **18** wherein the electrically connecting each of the data storage devices to the common printed circuit board is characterized by insertion forces in a first direction, and wherein the electrically connecting the common printed circuit board to an external circuit is characterized by an insertion force in a second direction substantially orthogonal to the first direction.

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